

Tropopause laminar cirrus and its role in total water budget near the lower stratosphere

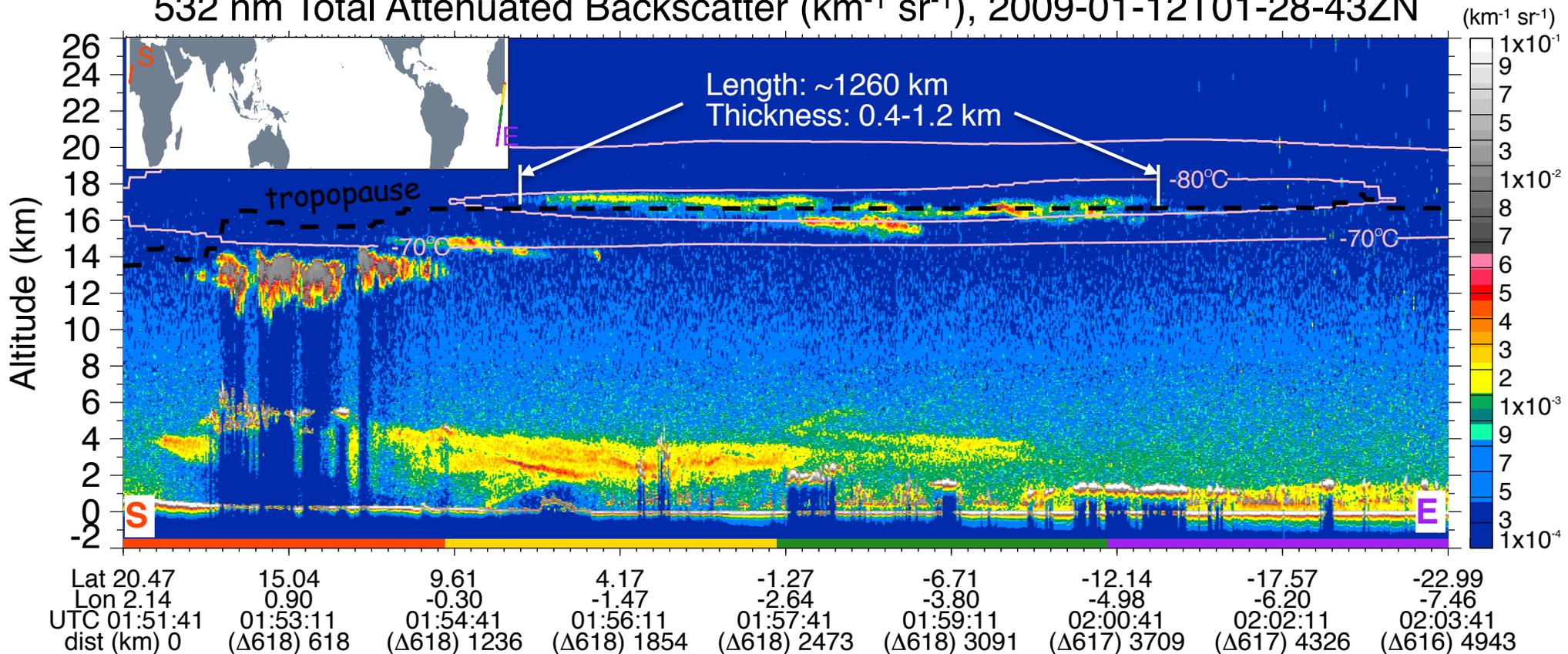
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Victoria Tsai (Stanford University)

Aura Science Meeting, Aug. 28, 2019
Funded by **NNH16ZDA001N-ACMAP**

Motivation:

Satellites constantly observe
 thin, isolated, extensive layer of cirrus (**laminar cirrus**)
 around the tropopause.

532 nm Total Attenuated Backscatter ($\text{km}^{-1} \text{sr}^{-1}$), 2009-01-12T01-28-43Z



Objective:

How often does laminar cirrus exist?

How much of ice amount does laminar cirrus carry?

What is the contribution of laminar cirrus to the total water budget?

Data & Method

1. Selection of laminar cirrus from CALIOP L1 backscatter (β'_{532p}) images
CALIOP $\beta'_{532p} \rightarrow$ IWC
2. Compare laminar IWC with MLS H₂O

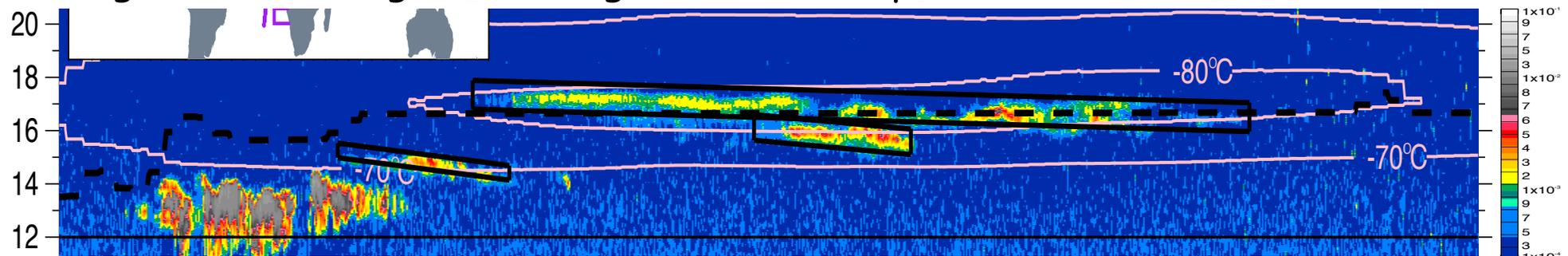
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Manual selection of laminar cirrus: 2009 January

Manual-method:

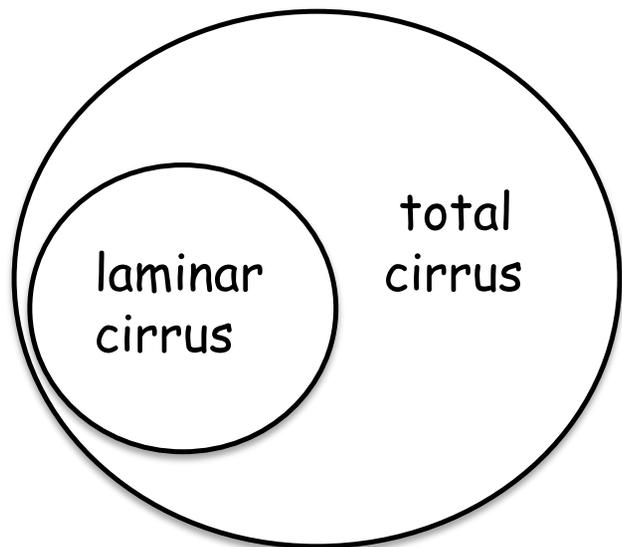
Digitize cloud edges [left, right, bottom, top]



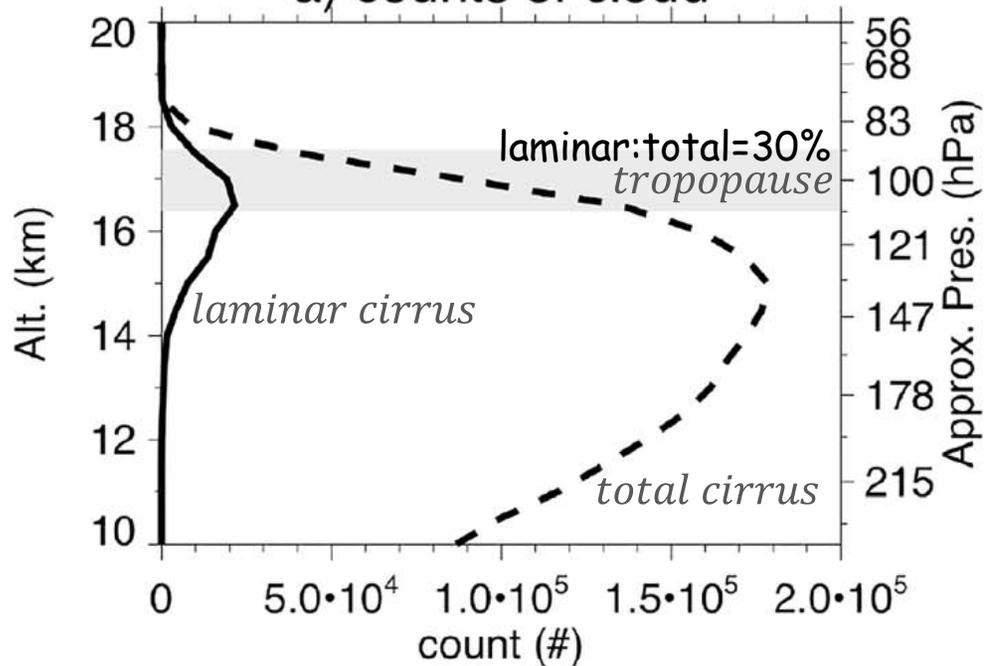
Features of most laminar cirrus in 2009 January

1. Length: 60 ~ 1800 km
2. Thickness: 0.2 ~ 1.7 km
3. Cloud top: 14.5 ~ 18.5 km
4. Distance from tropopause: -2 (below) ~ 1.5 (above) km
3. Optical depth: <0.03
4. Partial ice water path: <0.3 g/m²

total cirrus vs. laminar cirrus: 2009 January

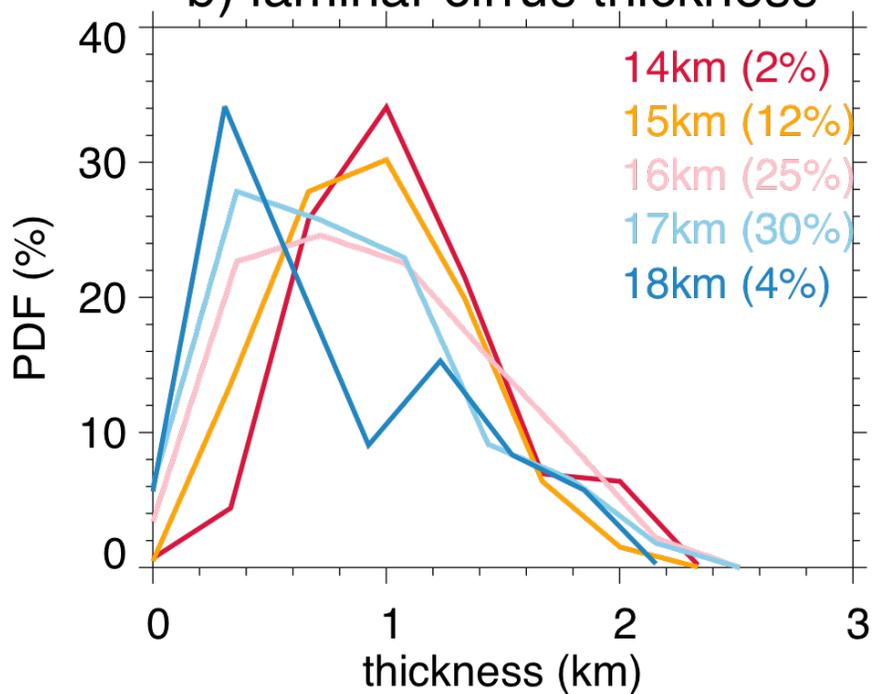


a) counts of cloud

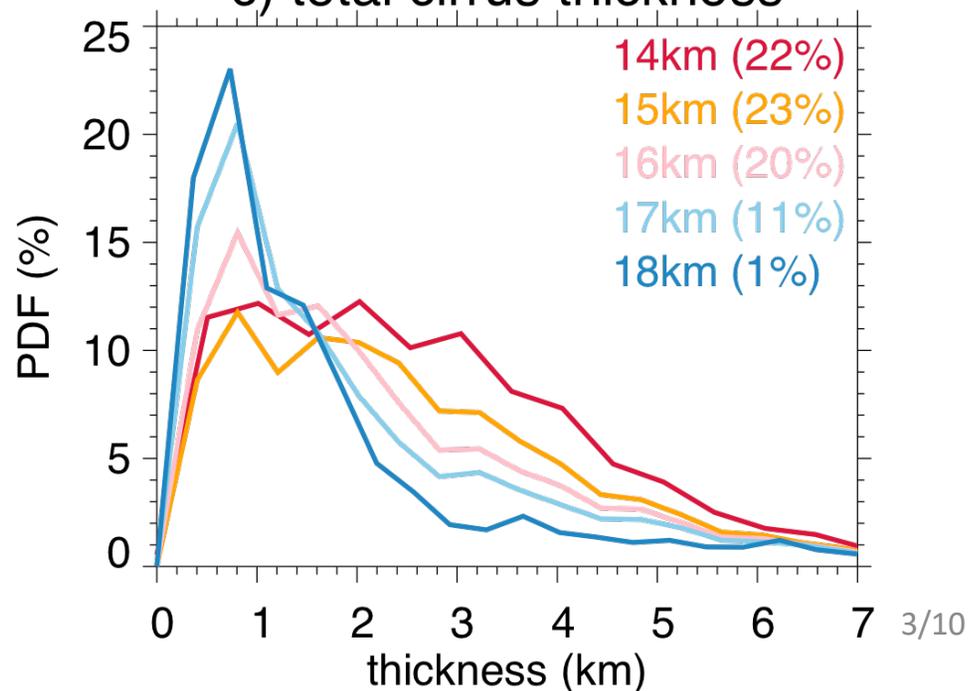


in terms of **cloud top & thickness...**

b) laminar cirrus thickness



c) total cirrus thickness

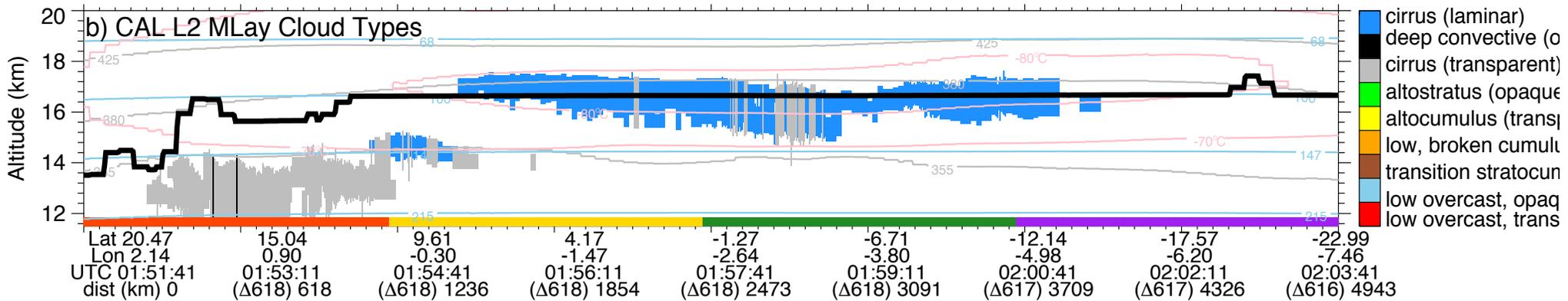


Build a long record of laminar cirrus for 10 years 2008-2017

Auto-method:

From CALIOP L2 merged layer product:

- **Known cirrus** identified, including thickness, top, IWC, etc.
- Further **auto-constrained** by laminar cirrus **features**
- **Easy** to build a **long-term records**

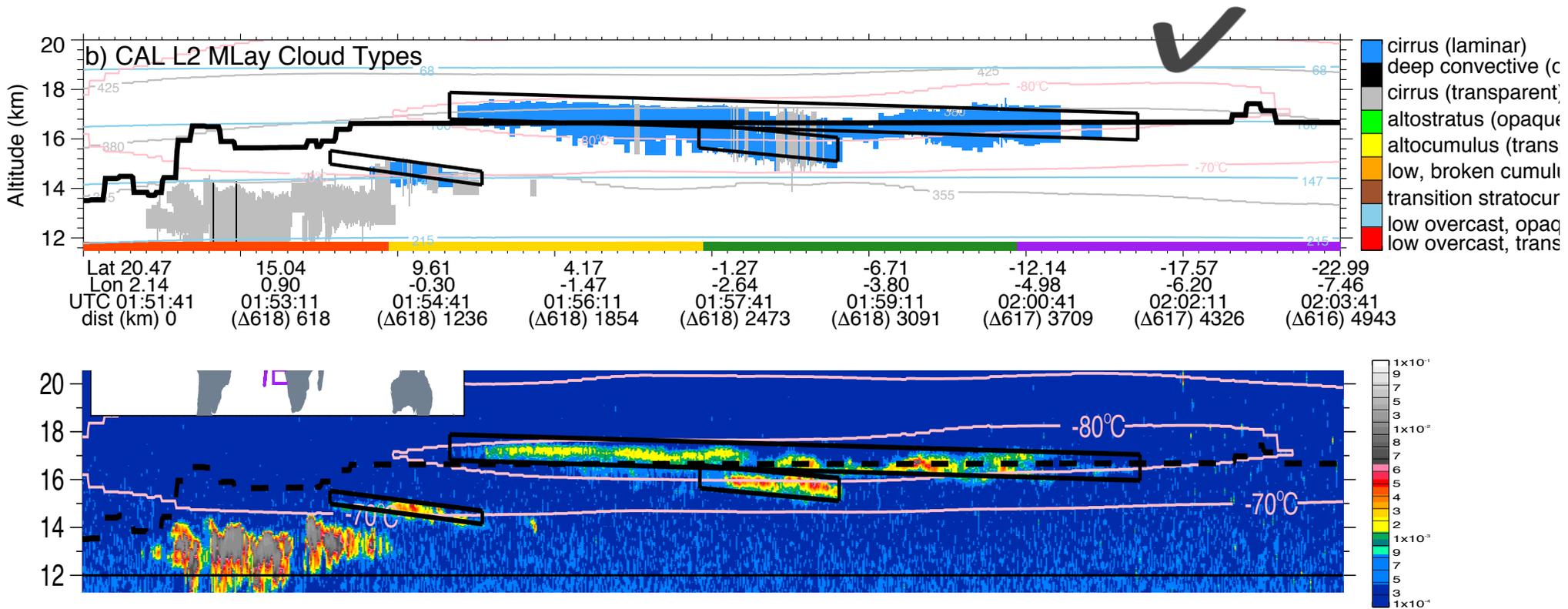


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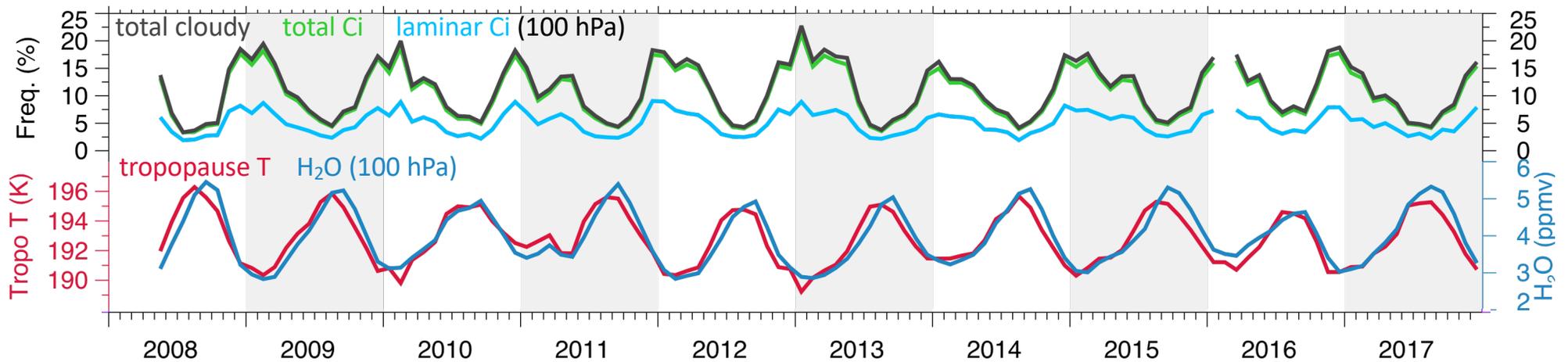
We could build a 10-year record in ~3 weeks on a regular server of 12-core i7

Caveat:

- Strongly depends on the cirrus type identified in L2 product
- Due to vertical averaging, some close layers might be considered one single layer

Annual cycle of laminar cirrus fraction: comparing to H₂O, tropoT, and BDC

Tropical 15° N-S average



More laminar cirrus during boreal wintertime, because:

colder tropopause

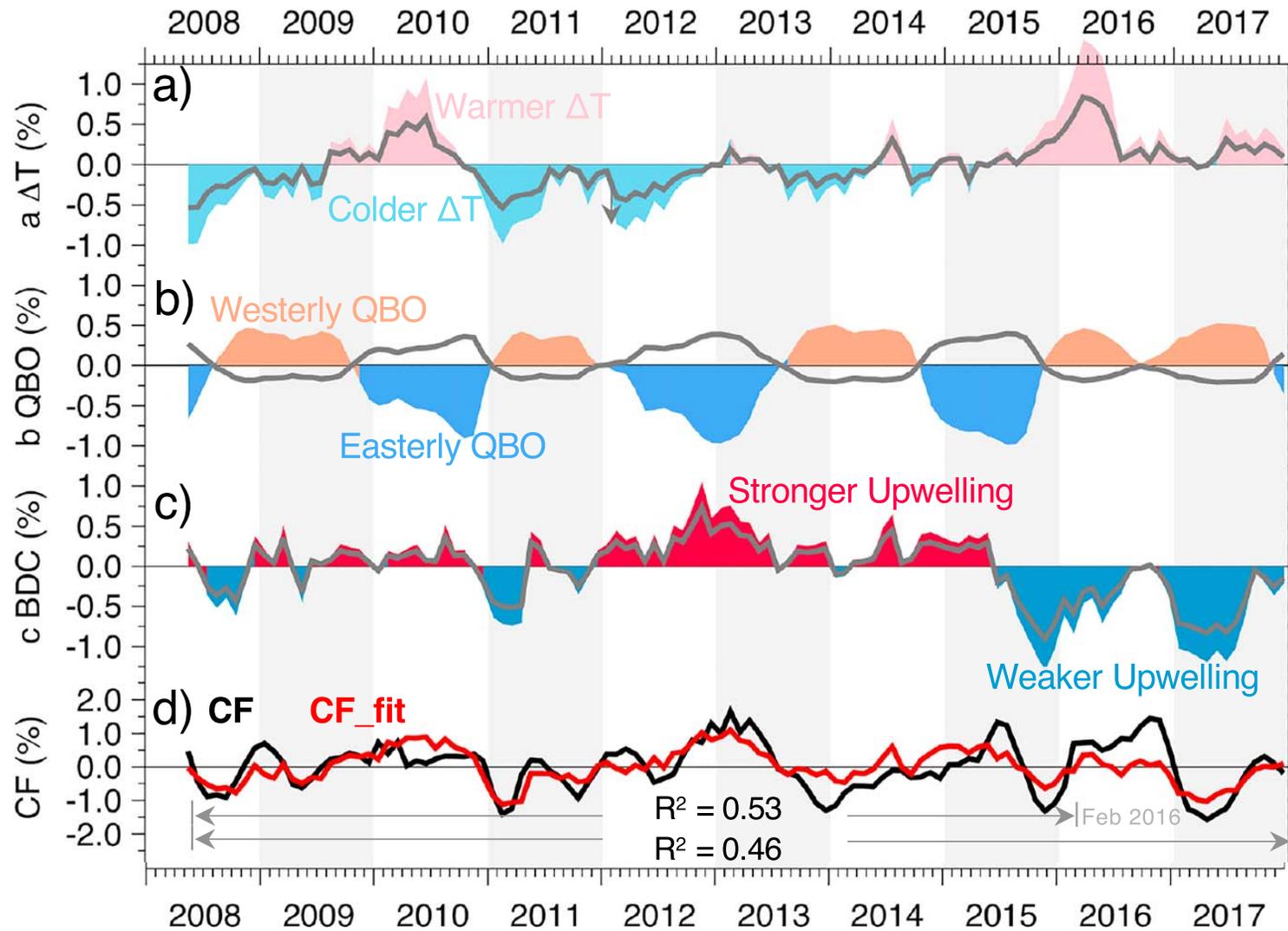
→ more frequent super(saturation)

→ more frequent dehydration that favors *in situ* formation of laminar cirrus

→ less H₂O

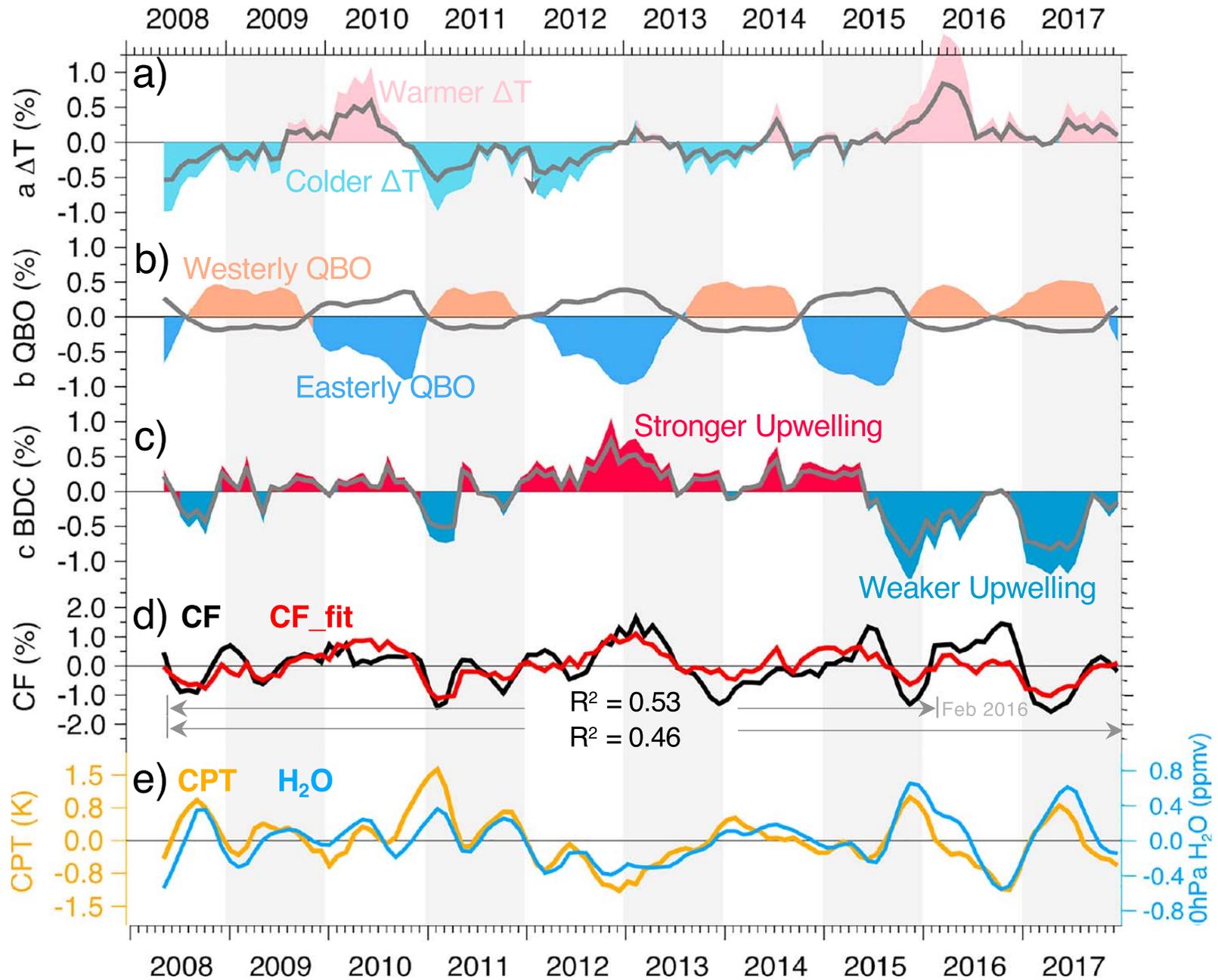
Interannual variability of laminar cirrus

$$\Delta CF_{\text{laminar cirrus}} = a \Delta T + b \text{QBO} + c \text{BDC} + \varepsilon$$



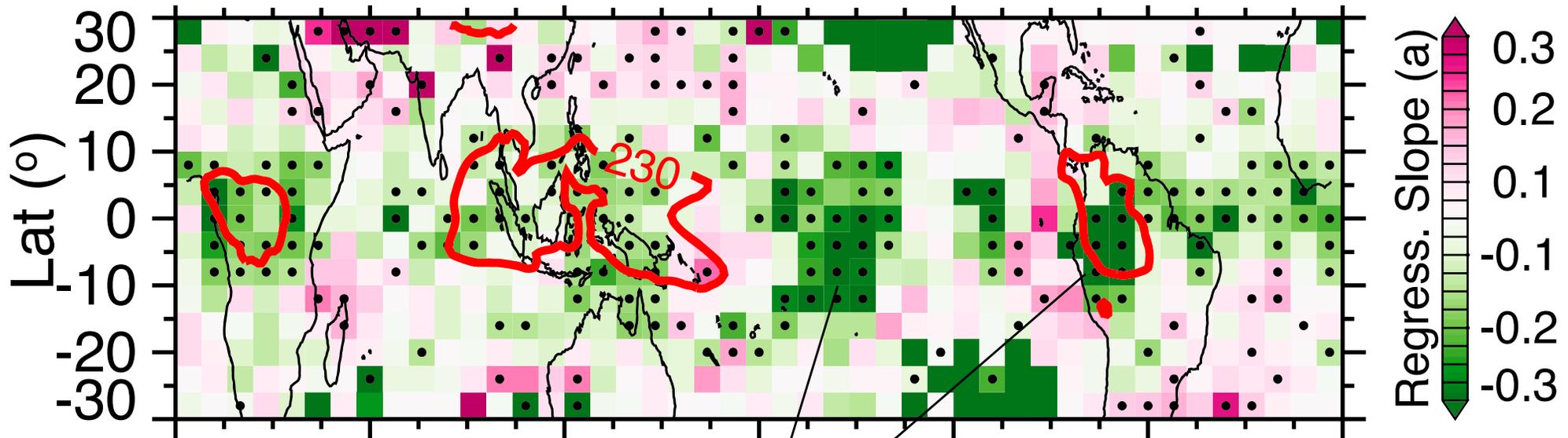
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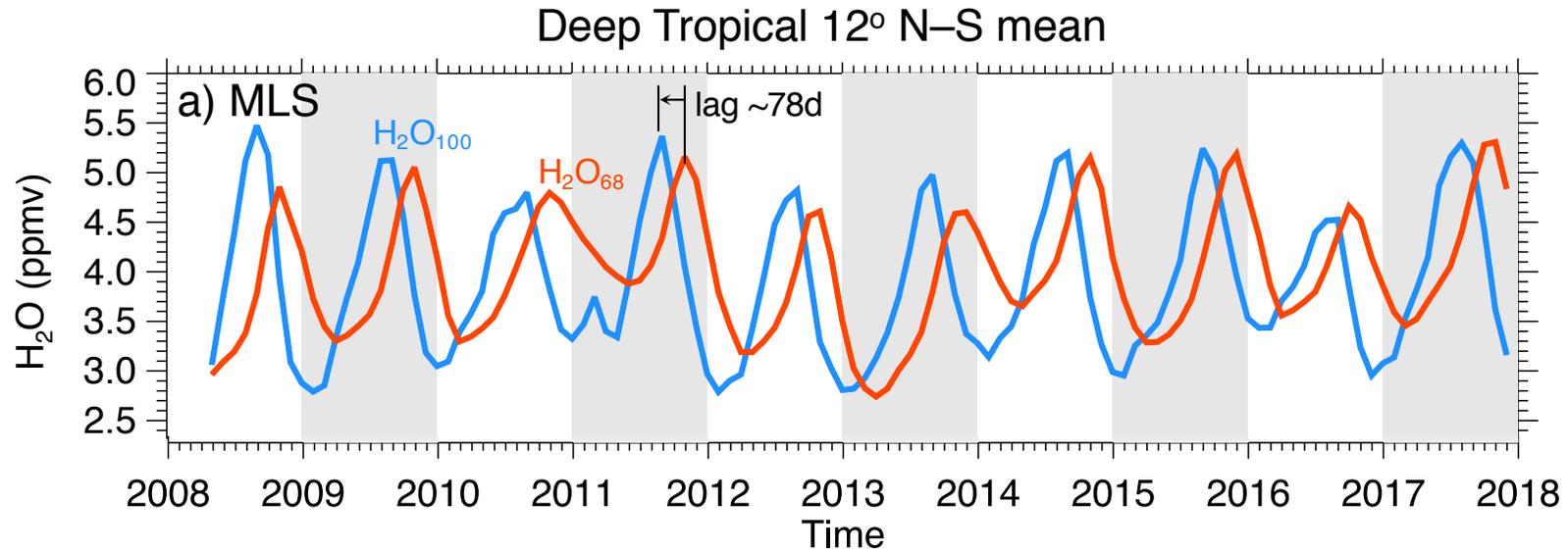
To quantify laminar cirrus IWC relation to H₂O @100 hPa

Slope "a" for regression $\Delta IWC = a \cdot \Delta H_2O + b$

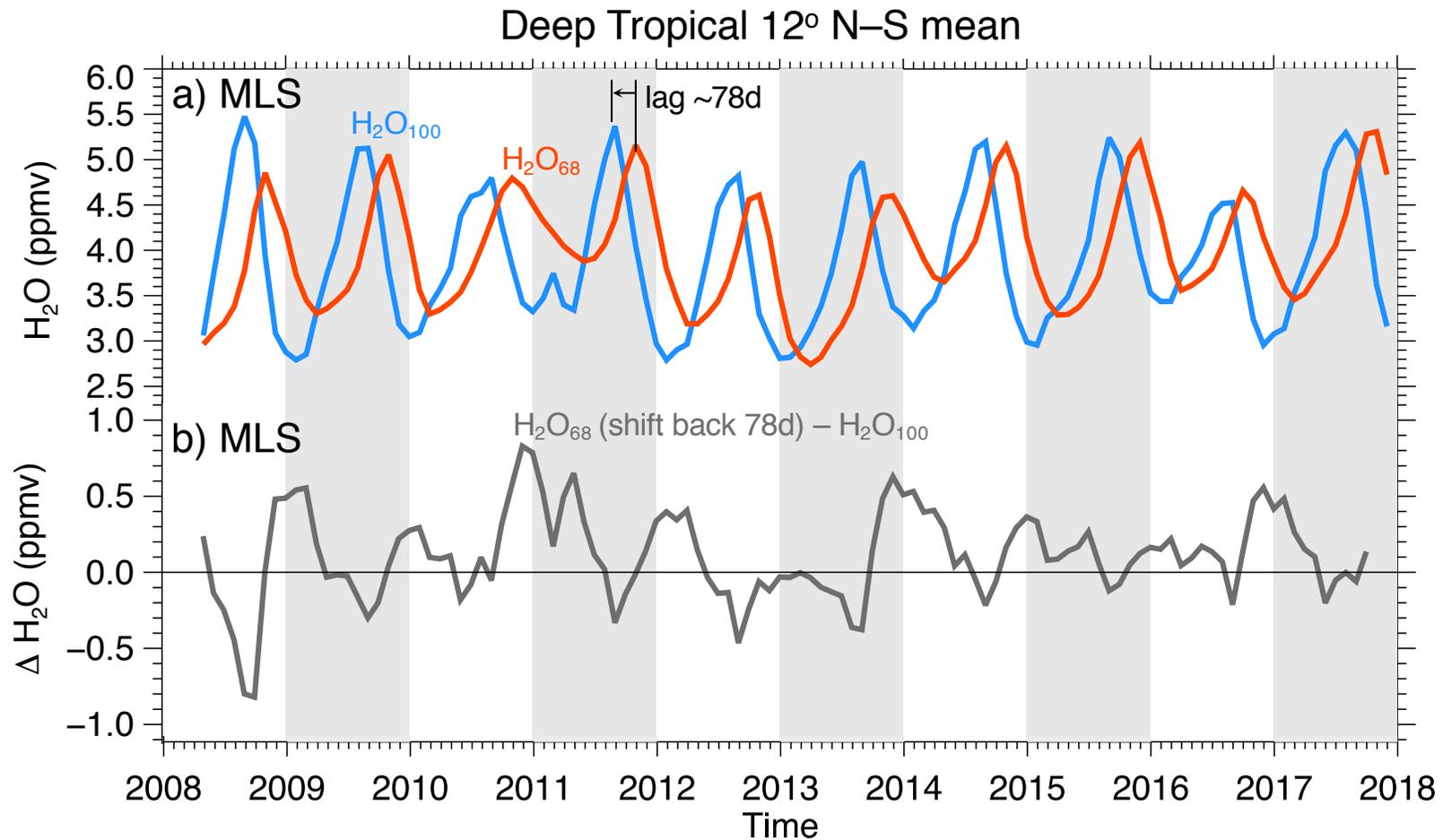


In laminar-rich region, **1 ppmv loss in H₂O** corresponds to **0.2-0.3 ppmv gain in laminar IWC**

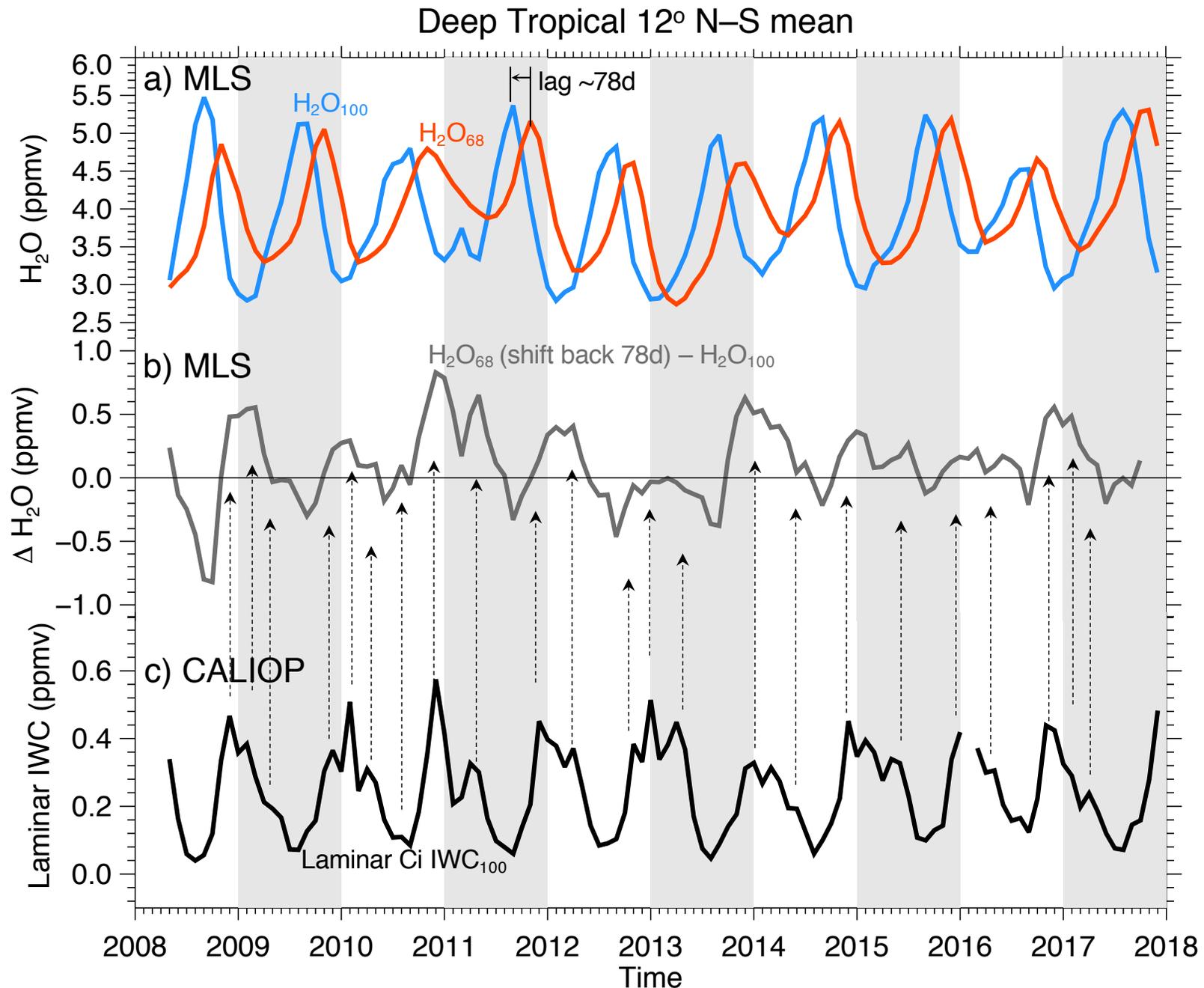
laminar cirrus could act as an important **transient water storage** and contribute to the total water budget in the lower stratosphere.



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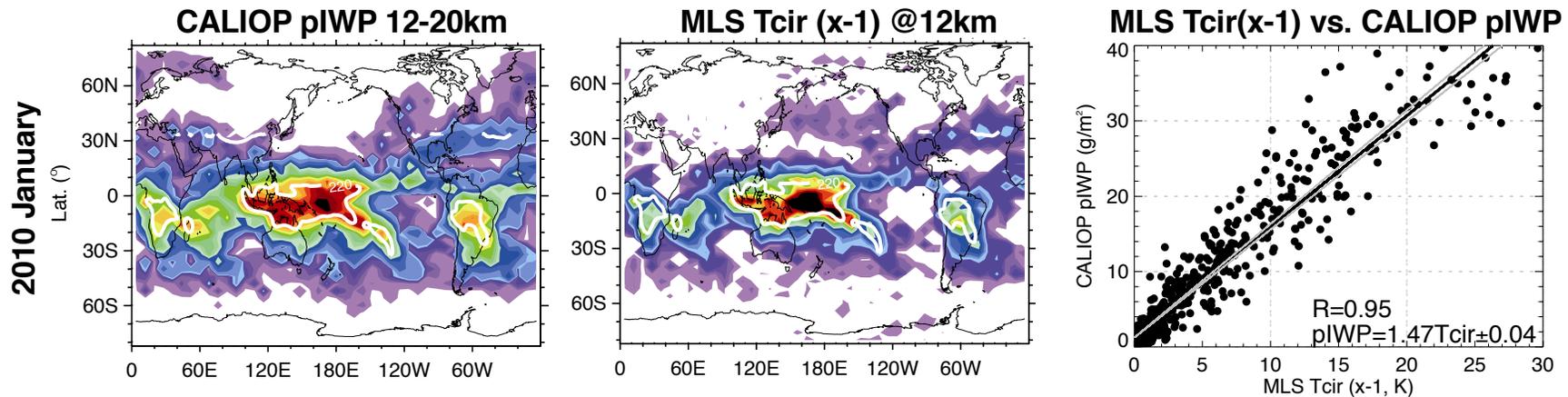
Concluding Remarks:

- From manual-selection, we obtained basic features of laminar cirrus
- Those features help us to auto-pick & build a 10-year records of laminar cirrus cloud-tops, thickness, optical depth, fraction, IWC, etc.

We found:

- Strongly anti-correlated between laminar IWC & H_2O : annually and interannually
- Laminar cirrus is more governed by the upwelling branch of BDC
(BDC strongly regulates variability of tropopause temperature)
- In laminar-rich region, 1 ppmv lost in H_2O \rightarrow 0.2-0.3 ppmv gain in laminar IWC
- Laminar cirrus could act as important transient water storage, contribute to total water budget

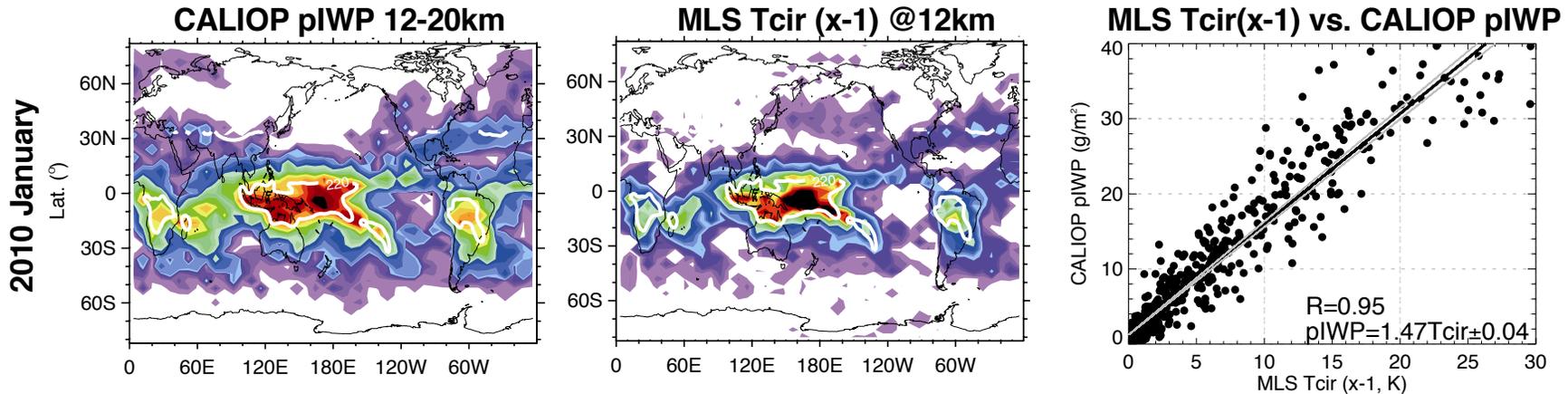
Ongoing projects:
rebuild a long-term record of pIWP from MLS 640-GHz Tcir



$$pIWP = \alpha Tcir_{640}$$

→ Regulated by CALIOP pIWP climatology for every 10° lat band

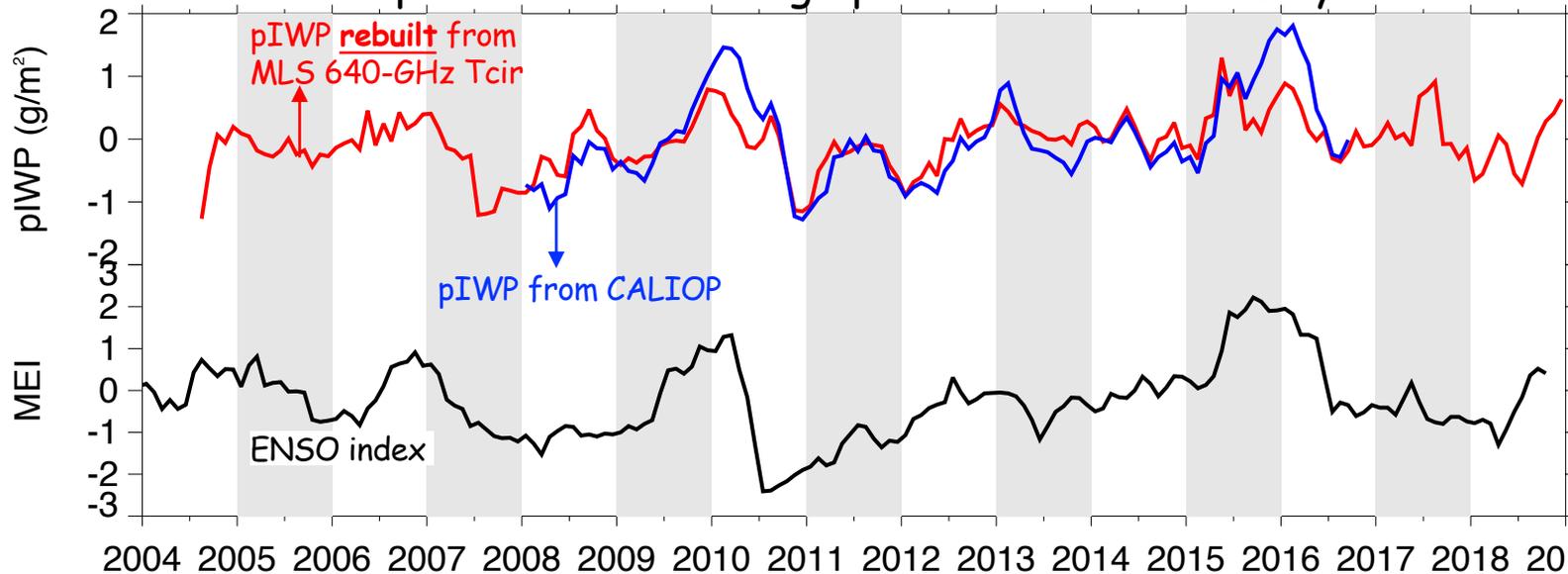
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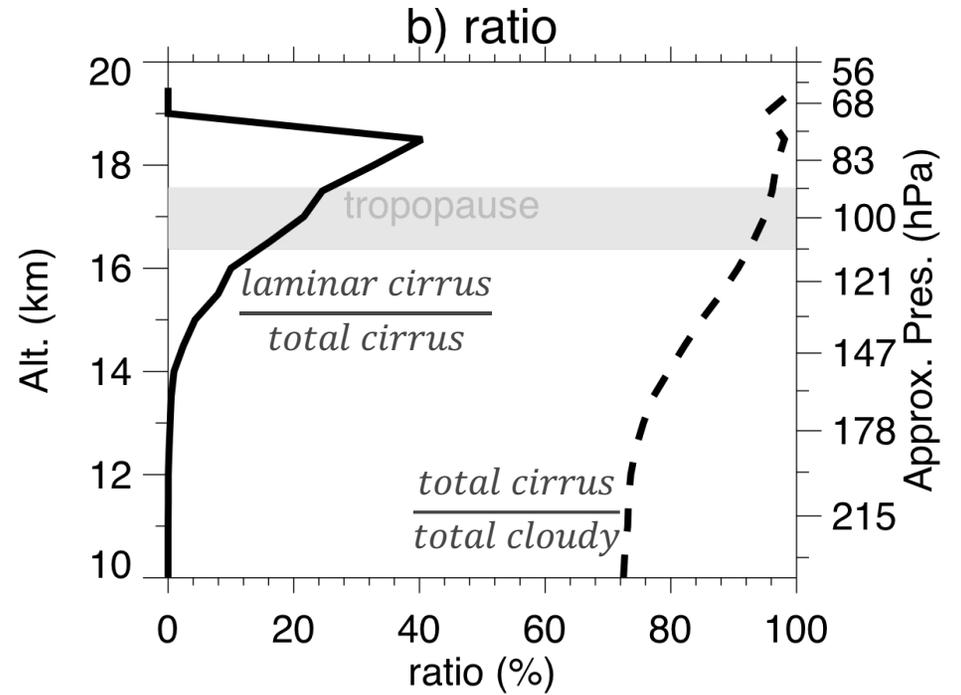
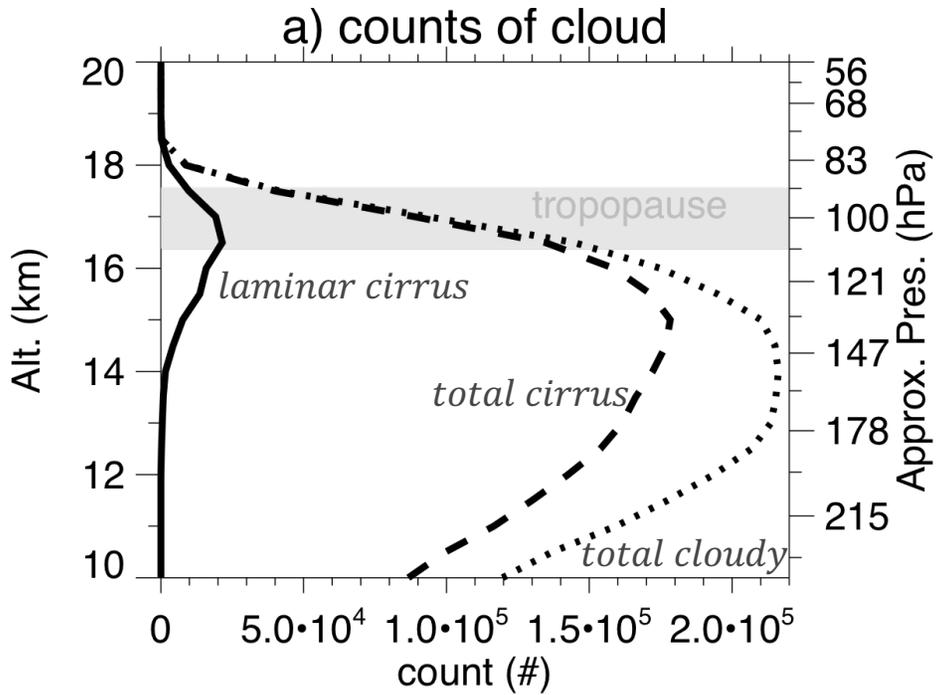
Regulated by CALIOP pIWP climatology for every 10° lat band

Tropical 10° N-S average pIWP 12-20km anomaly



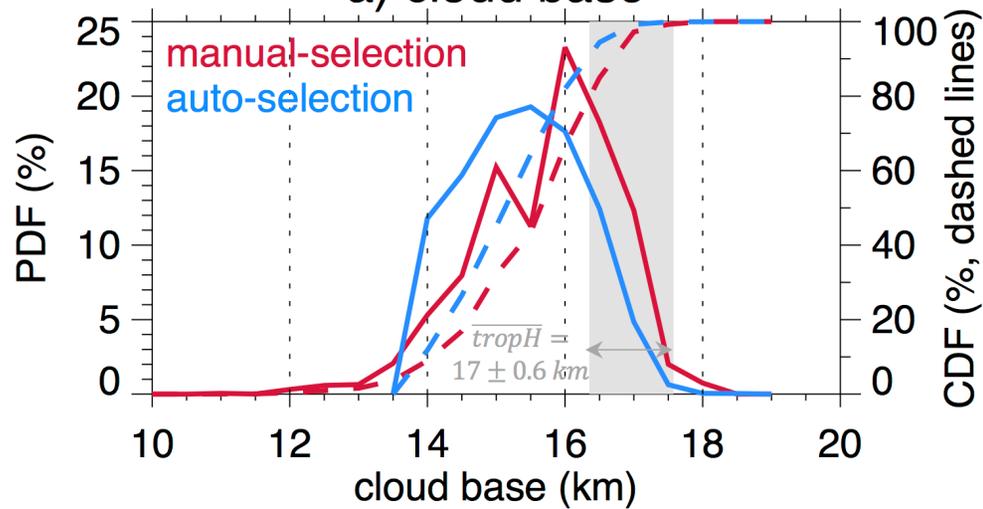
Wang, T., Wu, D.L., Gong, J., "Extended long-term observations of upper-tropospheric cloud ice from CALIOP and MLS", to be submitted to JGR.

Extra Slides

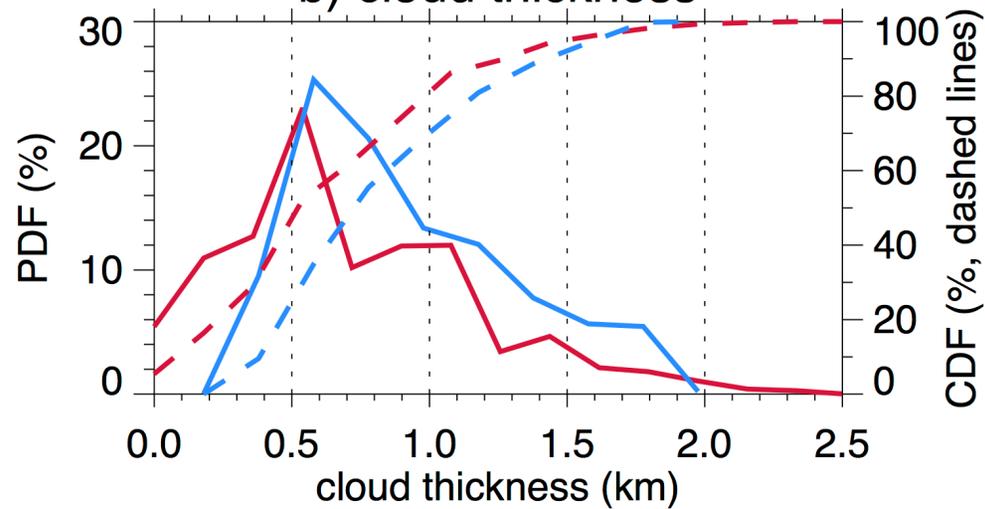


2009 January

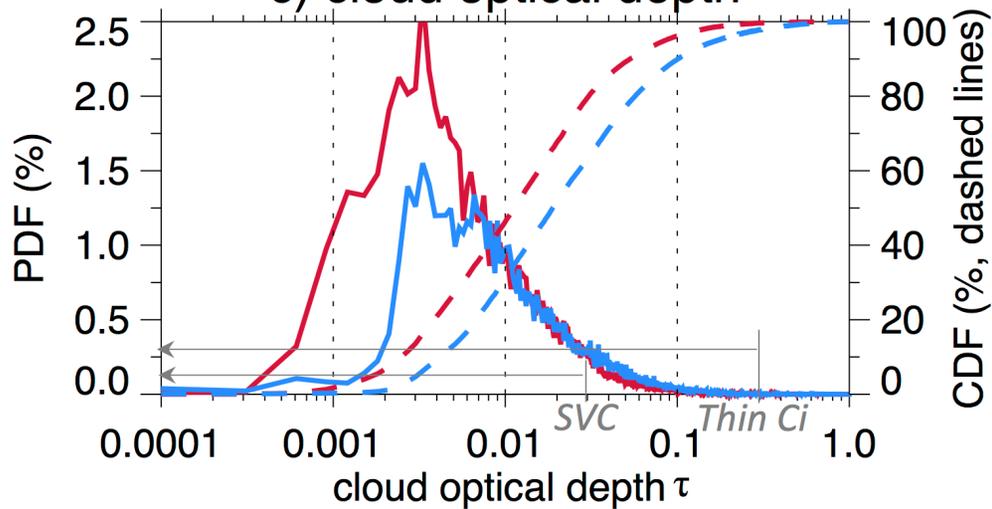
a) cloud base



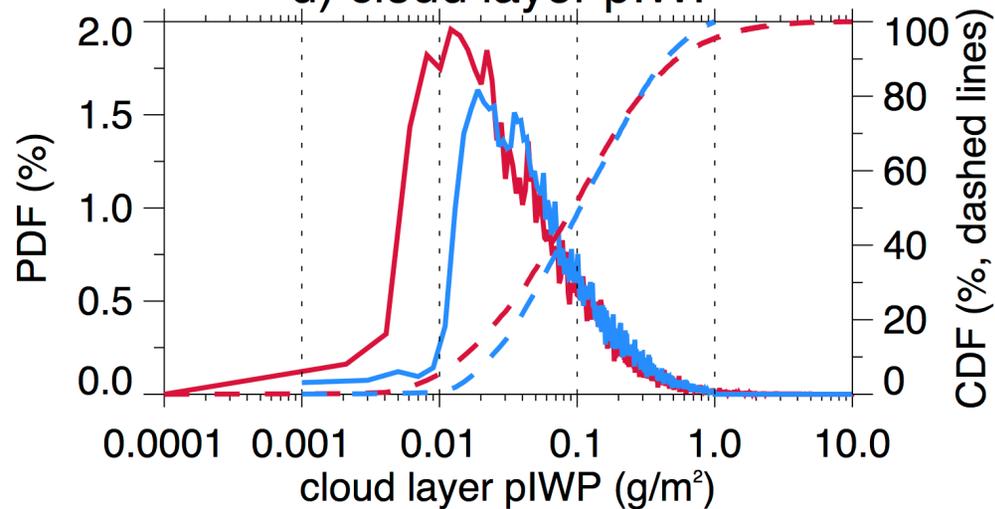
b) cloud thickness



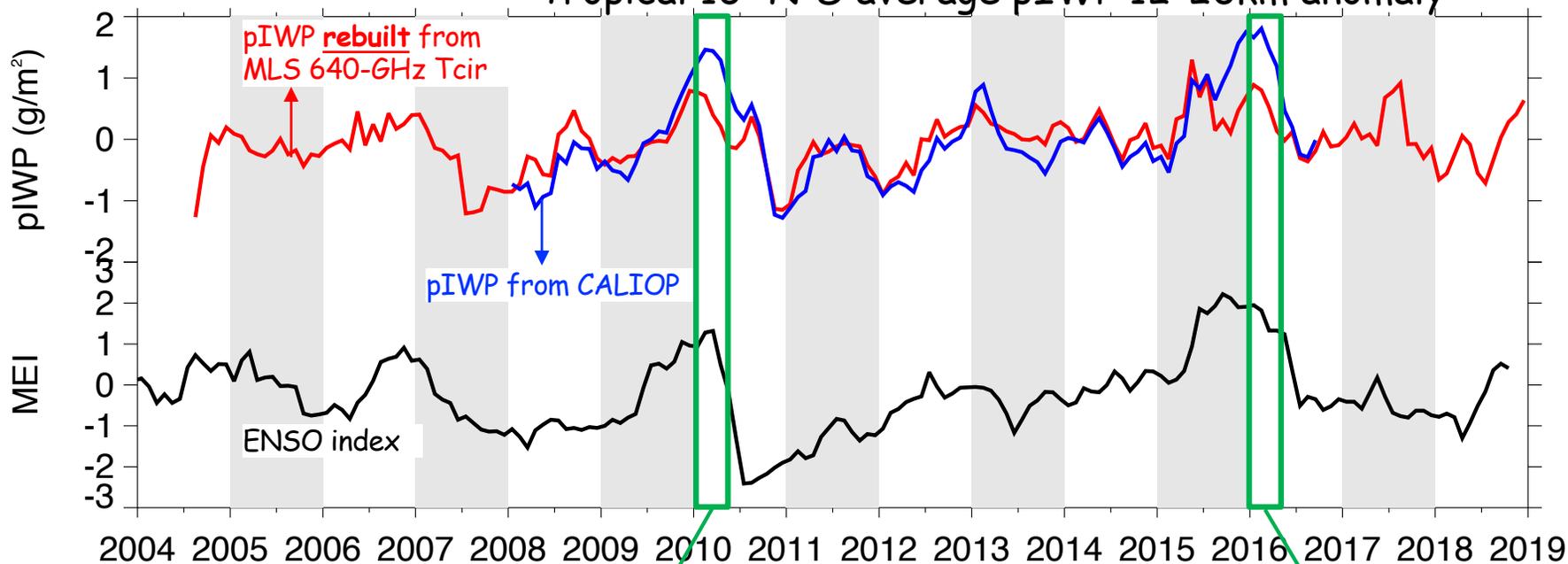
c) cloud optical depth



d) cloud layer pIWP

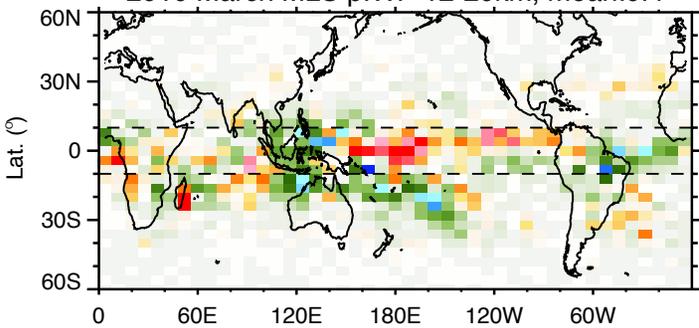


Tropical 10° N-S average pIWP 12-20km anomaly



2010 March

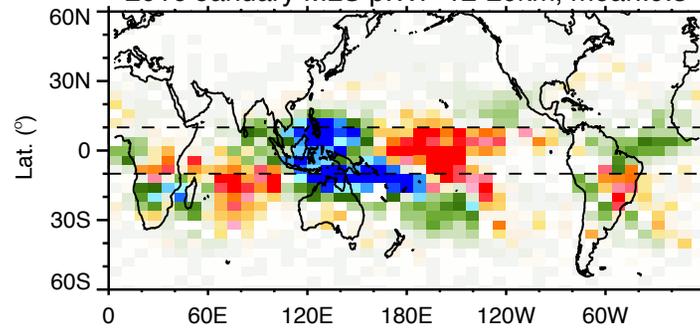
2010 March MLS pIWP 12-20km, mean:0.4



MLS pIWP f/
640GHz Tcir

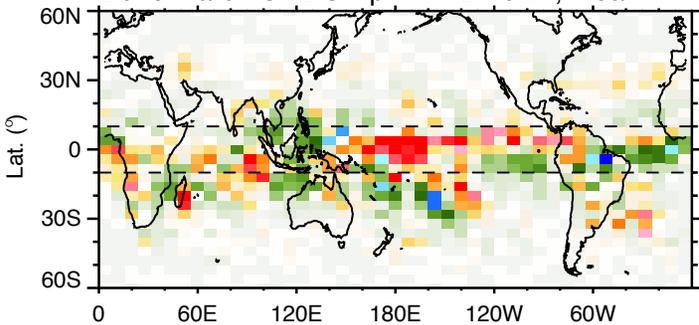
2016 January

2016 January MLS pIWP 12-20km, mean:0.3

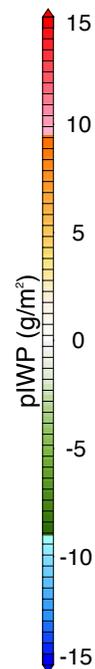
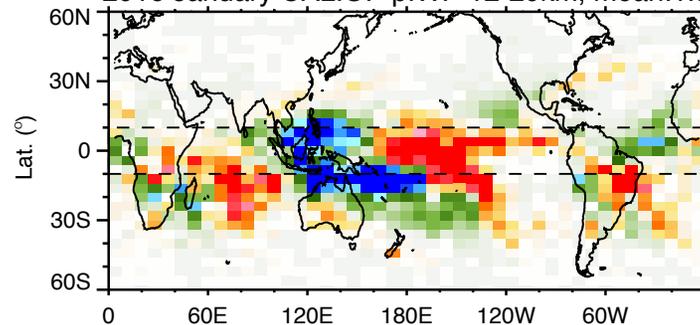


CALIOP pIWP

2010 March CALIOP pIWP 12-20km, mean:1.4

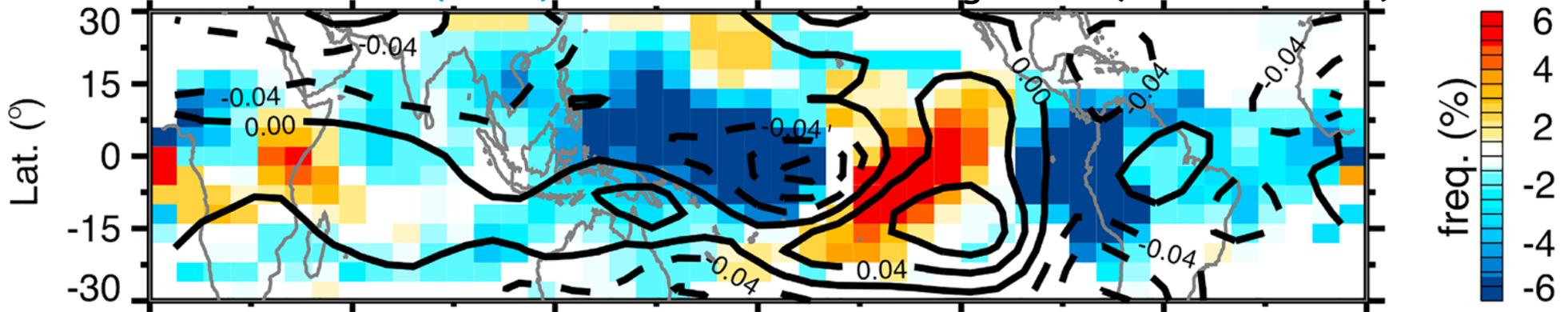


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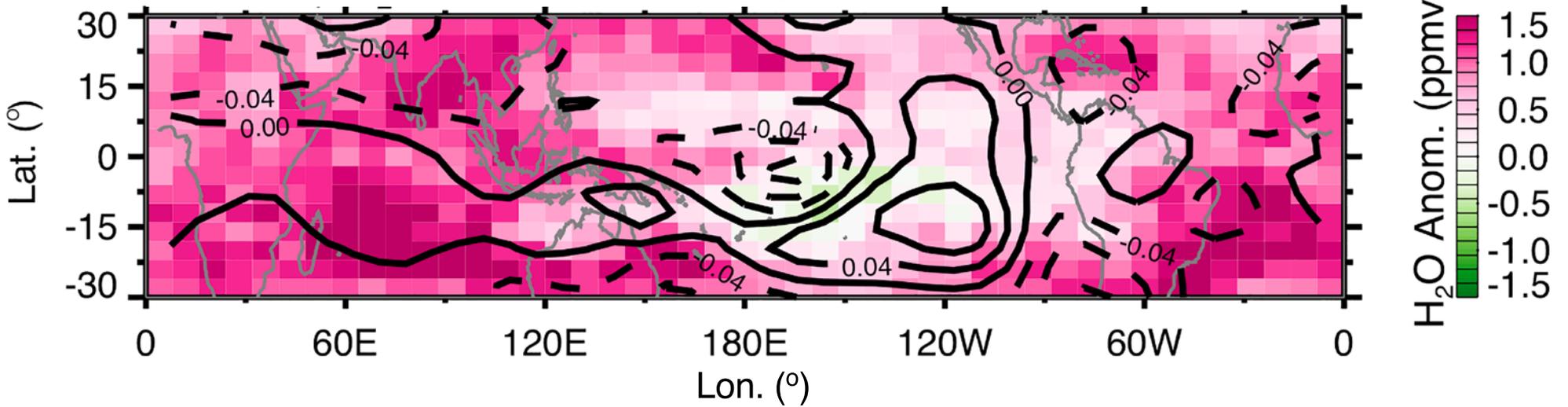


December 2015 - strong El Niño

Laminar cirrus (color); total diabatic heating rates (black contour)



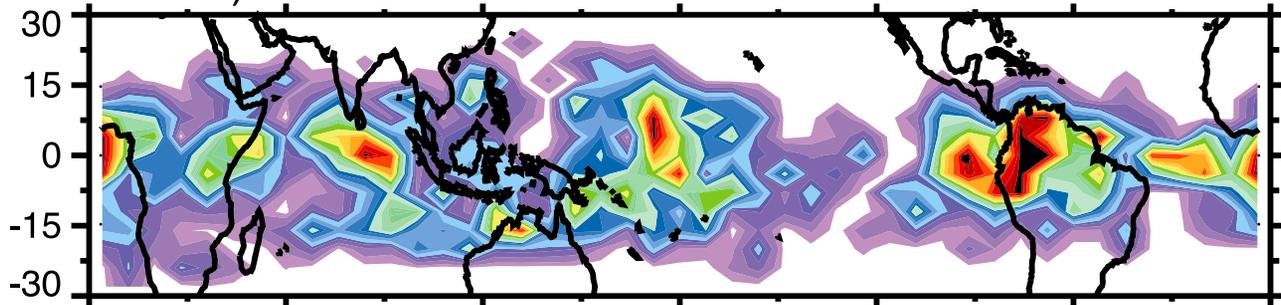
H₂O (color); total diabatic heating rates (black contour)



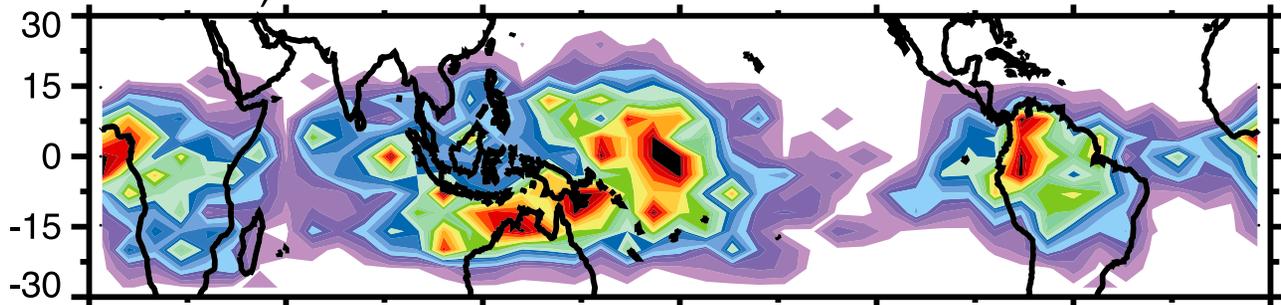
Auto-selection vs. manual-selection

2009 January

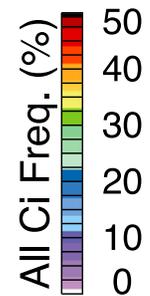
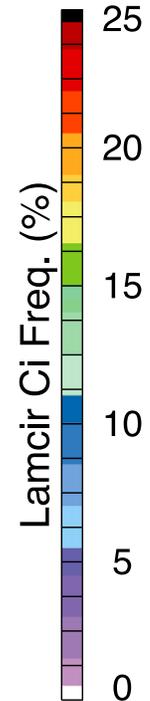
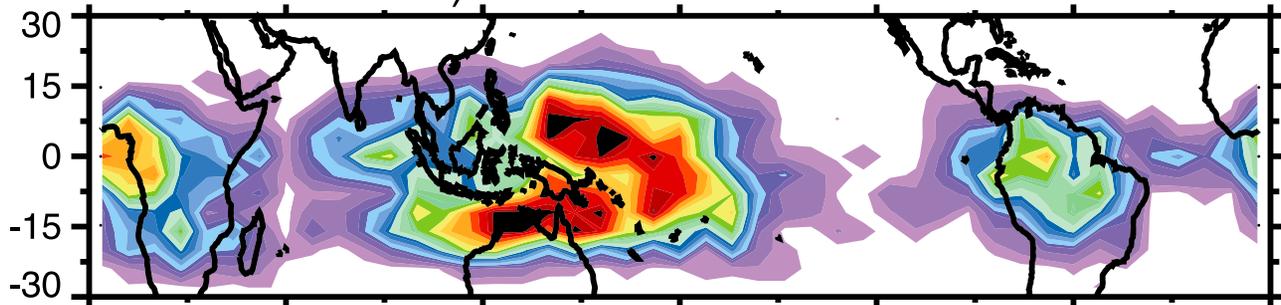
a) Laminar Cirrus @100hPa: Manual-Selection



b) Laminar Cirrus @100hPa: Auto-Selection

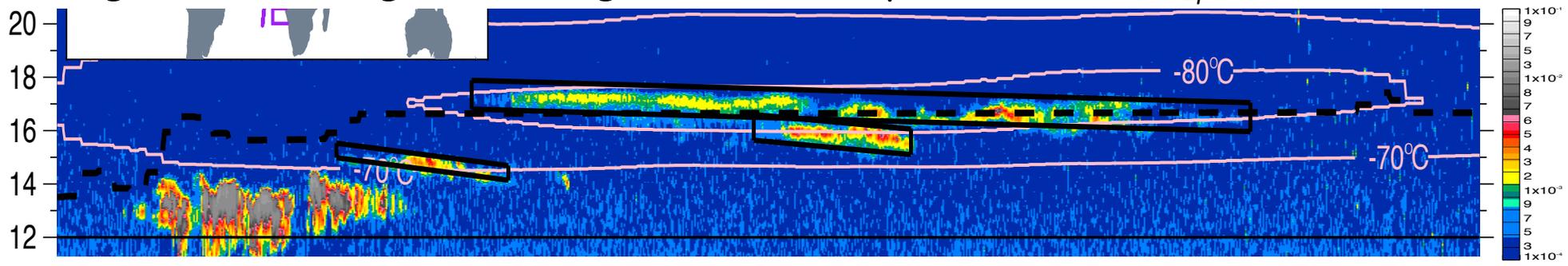


c) Total Cirrus @100hPa



human-aided selection of laminar cirrus

Digitize cloud edges [left, right, bottom, top]; find $\beta'_{532p} \rightarrow$ IWC



Find MLS H₂O

